2.2 Intersection Delay Studies

In addition to conducting travel time studies, intersection delay studies were conducted to evaluate the changes in operational performance due to signal timing modifications. While travel time studies are beneficial in assessing how well signal timings are coordinated between intersections and whether or not vehicles can progress through a series of intersections without being stopped, delay studies measure the average amount of time vehicles are stopped, or delayed, at signalized intersections. Furthermore, where travel time studies evaluate the performance of operations along the specific corridor, delay studies also measure vehicle delays on the cross-street approaches.

Stopped-vehicle delay was measured at 34 signalized intersections, as shown in Figure 4, by conducting stopped delay studies during the AM Peak, Midday and PM Peak time periods, both “before” and “after” new signal timings were implemented. At four of these locations, including the intersections of 27th/Holdrege Streets, 33rd/Vine Streets, 48th/Vine Streets and 48th/Holdrege Streets, delay studies were conducted two times, on separate days, to test the variability in vehicle delay resulting from collecting data on different days. These “dual studies” were performed for both the “before” and “after” conditions.

“Before” intersection delay studies were also conducted as part of Phase I of this project at 23 signalized intersections along the 27th Street and Highway 2 corridors during a low-volume, off-peak time period, which was identified from 10:30 p.m. to 12:00 midnight. Results of the “before” studies for the three peak time periods and the low-volume, off-peak time period have already been submitted as part of Phase I of this contract. “After” intersection delay studies were not conducted for the off-peak time period since no signal timing adjustments were made.

Delay studies were conducted on days experiencing “average” traffic conditions within the peak one-hour of each study time period. At each of these intersections, the average amount of stopped time each vehicle/driver experienced was estimated by counting the number of vehicles observed as “stopped” at 13-second intervals, for each approach of the intersection. By making the assumption that each observed vehicle was stopped for the entire 13-second interval, the number of observed vehicles is multiplied by 13 seconds to obtain the total amount of intersection delay. This number is then divided by the total traffic volume to determine the average delay per vehicle for the entire intersection.

Delay is a complex measure and is dependent on a number of variables, including quality of progression, traffic volumes, signal timing parameters and intersection capacity. Another way of expressing delay is in the form of level-of-service (LOS). Specifically, LOS criteria are stated in terms of the average delay per vehicle.

It should be noted that the vehicle delay measured in the field is termed stopped vehicle delay, and represents the amount of time a vehicle is stopped at a red light. This is the type of delay utilized by the 1994 *Highway Capacity Manual*. Recent revisions to this document, beginning with the 1997 version and most recently, the 2000 version, have used control delay to identify the LOS intersections are operating under. Control delay is the portion of the total delay attributed to traffic signal operation for signalized intersections. The LOS criteria for stopped delay and control delay are summarized in Table 15.

Control delay includes initial deceleration delay, queue move-up time, stopped delay and final acceleration delay. According to the 2000 *Highway Capacity Manual* (HCM), control delay is approximately 30% greater than stopped delay. Since it is difficult to measure control delay in the field for every vehicle approaching an intersection, stopped delay was measured, as outlined in ITE's *Manual of Transportation Engineering Studies*, multiplied by 1.3, and cross-referenced to Table 15 to identify what LOS the intersection is operating under per the 2000 HCM criteria. Throughout the remainder of this chapter, references to intersection LOS pertain to the 2000 HCM criteria.

Reasons for different improvements in intersection delay versus average travel-speed on study corridors are twofold. One, when performing the traffic signal optimization analysis, attention was given to the intersection approaches on the study corridors as well as the approaches of the cross-streets. Therefore, many of the reductions in intersection delay are a result of decreases in delay on all four approaches to the intersection and not just the two approaches pertaining to the study corridors. These improvements for cross-street traffic are not represented in the analysis of the travel-time corridors. The second reason for the greater improvements in intersection delay relates to the sub-system analysis. Sub-system analysis was performed as part of the signal timing analysis and will be discussed in Section 4.0. Many of the decreases in average travel-speed are a result of increased delays at the intersections where sub-systems are broken. The remaining intersections are experiencing efficient operation in terms of both signal timings and progression, which result in lower delays.

The following six sections summarize the results of the "before" and "after" intersection delay studies conducted at locations along each of the six corridors. Detailed "after" intersection delay summaries for each intersection are provided in Appendix B. Summaries of the "before" intersection delay studies were previously submitted as part of Phase I of this project. Dates when intersection delay studies were conducted are also provided in Appendix B